Considerations for a Multi-purpose Agrobot Design Toward Automating Skillful Viticultural Tasks: A Study in Northern Greece Vineyards

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Abstract

Seasonal labor shortages in agriculture are experienced throughout Europe and beyond especially, but not only, during the harvest time when the demand for hands is high as well as urgent. Agrobots have been established as a sustainable solution to support these growing demands due to their capacity to work incessantly, fast as well as with skillful precision. In the aforementioned context, this work investigates the design of a single multi-purpose robotic system towards automation of a number of skillful viticultural practices. Best practices are recorded thoroughly according to the needs of local northern Greek wineries through interviews with experts. Possibilities and limitations for robotic implementation are discussed and appropriate end-effectors are outlined.

Keywords

Precision agriculture, agricultural robot, viticultural practices, vineyard, automation

1. Introduction

The quality of grapes and produced wine is directly affected by the terroir of wine and both growing and winemaking practices [1,2]. Canopy manipulation practices are traditionally performed by experienced workers. However, the vast cultivation areas due to production growing demands in conjunction to the lack of seasonal labor yell for robotic interventions to automize viticultural seasonal practices in a dexterous and consistent way.

Agricultural robots, namely Agrobots [3], have been sparingly used in viticultural automation [4]; for harvesting [5], spraying [6], berry thinning [7], pruning [8], monitoring [9]. However, certain highly skillful tasks, such as shoot thinning or tying, have not yet been automated. Less detailed tasks, such as top/lateral removal, have been automated with appropriate tools mounted on tractors, yet, not altogether by a single muti-purpose agrobot. The challenge is for an agrobot or group of robots [10], to automate a multitude of viticultural practices with minimal adaptations of suitable tools/end-effectors.

Towards this end, this work investigates the design of a multi-purpose robotic system for the automated vineyard management practices of harvest, cluster thinning, leaf removal, pruning, shoot thinning, top (topping) and lateral removal, weed removal, spraying, and tying. The focus is on optimal requirements of practices as delineated by expert oenologists and agronomist based on the needs and

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characteristics of Northern Greek vineyards. For each of the practices, appropriate end-effectors are proposed. The scope is to investigate possibilities and limitations of robotic implementation of a set of basic viticultural practices which in their entirety have never been automated yet by a single robotic system.

The remainder of the paper is as follows: optimal viticultural practices are described in Section 2; requirements for appropriate end-effectors and challenges are included; Section 3 concludes the paper.

2. Optimal Viticultural Practices

Optimal viticultural practices are extracted through interviews with expert agronomists and oenologists of three wineries of Kavala and Drama, in Northern Greece, under the ongoing project SVtech [11]. Interviews took place in August 2021 and were conducted by teams of engineers and computer scientists who will consequently design the final robotic system. In what follows, all tasks are determined. Suggested end-effectors and challenges towards robotic automation are included in Table 1.

2.1. Cutting Tasks

The following subsections describe an array of cutting tasks including harvest and cluster thinning, leaf removal, pruning, shoot thinning, top and lateral shoot removal, and weed removal.

2.1.1. Harvest and Cluster Thinning

Harvest is the collection of all fully and equally ripened grape clusters. The process includes cutting grape bunches off the vine and collecting them into harvest crates [12]. Cluster thinning is employed to improve foliage-yield relationship by selecting and removing bunches that are not uniformly ripened, of smaller size, defected or belong on the outer edge of the vine [13].

In both tasks bunches are cut-off from the stem, therefore, they can be automated with the same end-effector. In manual harvest, the harvester grasps the cluster with the non-dominant hand and cuts it free with the dominant hand by using a grape picking scissors. Thus, the automated system needs end-effector(s) able cut the grape cluster from the stem and hold it.

2.1.2. Leaf Removal

Leaf removal refers to the modification of the microclimate of foliage, by removing leaves from the base of the shoots in the cluster zone, towards a better exposure to the sun [14]. Leaf removal varies depending on the grape variety; less leaves in white and more in red varieties are removed. Regardless the variety, leaf removal is traditionally performed manually. Leaves are removed easily with a sharp motion pulling the leaf downwards with the hand. Therefore, leaves removal can be automated by using an appropriate end-effector that could grasp and remove leaves.

2.1.3. Pruning

Winter pruning is one of the most important viticultural practices due to its physiological and productive effect on plants [15]. There are several ways to prune a vine depending on the variety. Thus, a basic and generic automated approach is extracted; the canes for renewal are selected and cut back to two canes each; the rest of the wood is cut off and removed; manual trimming can be performed afterwards whenever highly specialized pruning techniques are needed.

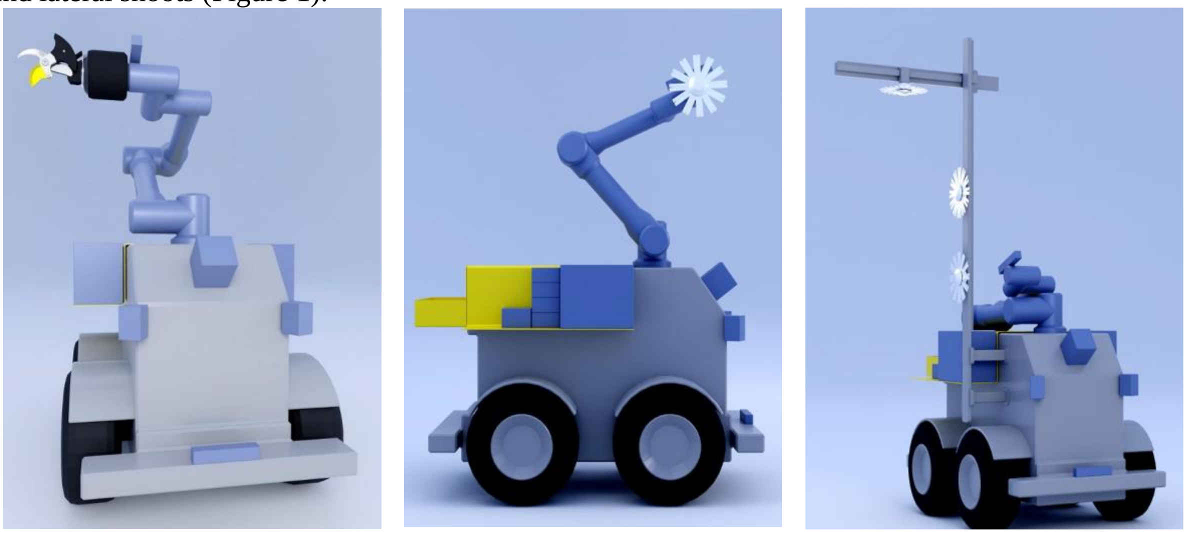
Manual pruning is still prevalent and performed by experienced workers using secateurs with a parrot beak; the worker holds the cane with the non-dominant hand and cuts it with the dominant hand; the cut wood is removed with the non-dominant hand. Thus, the automated system needs to hold the cane, cut it and remove it, by using an electric cutting pruning tool and a holding tool.

2.1.4. Shoot Thinning

In shoot thinning, it is decided how many buds the whole vine can carry; buds are counted and adjusted according to desired fruit load [16]. Less shoots result in fewer grape clusters with concentrated flavors. This practice requires delicate handling since shoots are very tender and easily cut. Traditionally shoots are manually removed by experienced workers. Therefore, a shoot thinning tool needs to be able to replace a human dexterous hand.

2.1.5. Top and Lateral Shoot Removal

Cutting off the shoots that have grown at the sides and above the higher wire at flowering, results in more carbohydrates and nutrient to the grape clusters [17]. Topping is usually done manually with a folding secateur. In commercial vineyards, which are vast and linearly structured, topping is performed mechanically with a tool with cutting bars adapted to a tractor (topping machine). Along with the tops, cutting of the sides is done at the same time. The automated system needs a cutting tool for both top and lateral shoots (Figure 1).



(a) (b) (c)

Figure 1: Automation of top and lateral shoots removal with (a) a folding secateur tool, (b) a trimming tool and (c) a customized topping machine.

2.1.6. Weed Removal

Removing the weed is to limit its competition for water and nutrients with the vine, maintain a good microclimate and soil fertility [18]. In commercial vineyards, weed removal is done mechanically with a weeding machine adjusted to tractors. For the automation of weed removal, a commercial under-row weeding machine can be adjusted to a ground robot.

Table 1
Potential end-effectors, requirements, and limitations for the automation of each viticultural practice by autonomous agrobot/s

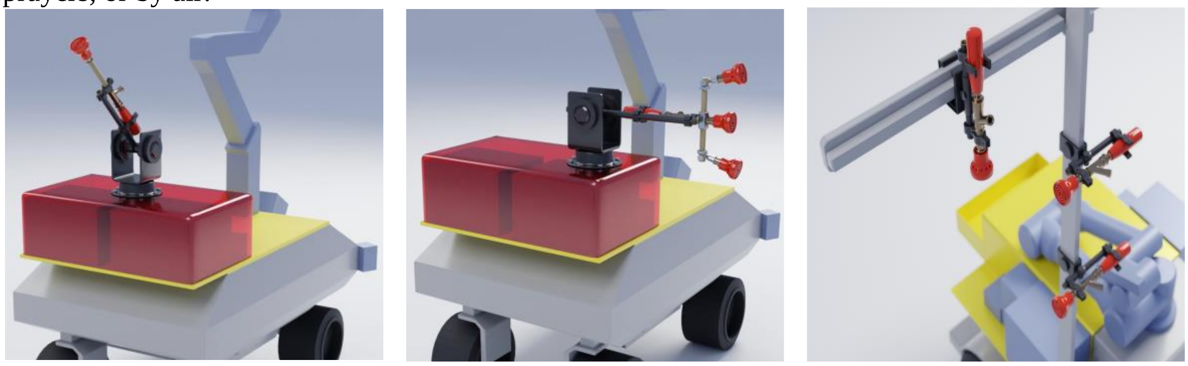
Viticultural task	End-effector tool (robotic system)	Requirements	Challenges and limitations
Harvest and Cluster thinning	• Simultaneous cutting-and-holding tool (one arm-one robot) • Cutting tool and holding tool (two arms-two robots or two arms-one robot)	Cutting tool: sharp, durable, light, with commercial picking scissors blades. Holding tool: able to hold from large to small objects with adjustable power (e.g., commercial gripper or a 5-finger robotic hand simulating the non-dominant hand of a human harvester).	• Degree of maturity determination • Determination of bunches to remove • Stem/bunch detection with environmental noise • Cutting and holding without injuring grapes
Leaf removal	• Grasping tool (one arm-one robot) • 5-finger robotic hand (one arm-one robot)	Grasping tool: light, durable, adequate opening.	• Grasping of brunches/wires • Applied torque • Removing leaves without injuring grapes • Determine percentage of removed leaves based on variety • Uniform leaf removal • Foliage detection and density determination
Pruning	• Cutting tool and holding tool (two arms-one robot or two arms-two robots)	Electric pruning cutting tool: same as in harvest but with secateurs blades. Holding tool: same as in harvest.	• Cane determination • Cutting without injuring the vine • Cutting and holding simultaneously • Removing wood
Shoot thinning	• Shoot thinning tool (one arm-one robot)	Shoot thinning tool: a robotic 5-fingers hand.	• Adjust the number of buds to remove • Remove bud without injuring the cane • Bud number determination
Top and Lateral shoot removal	• Secateur tool (Figure 1(a)) (one arm-one robot) • Trimming tool (Figure 1(b)) (one arm-one robot) • Topping machine (Figure 1(c)) (one robot)	Topping tool: sharp rotatable blades, durable, light, easily adjustable to a ground robot and to the height of the vine.	• Adjust the tool to vine height • Remove shoots without injuring vine
Weed removal	• Under-row weed control tool (one robot)	Weed removal tool: cut the weed underneath vines, sufficient working width, light, height-adjustable, sharp and durable blades.	• Under-row weed control • Cutting without injuring trunks • Adjust the tool to desired height • Trunk/structures detection and avoidance

Table 2 (cont.)

Viticultural task	End-effector tool (robotic system)	Requirements	Challenges and limitations
Spraying	• Moving spraying tube tool (Figure 2(a)) (one robot) • Moving multiple spray nozzle tool (Figure 2(b)) (one robot) • Customized spraying machine (Figure 2(c)) (one robot)	Spraying tool: targeted spraying.	• Adjust the tool to desired direction/orientation/height • Restriction of pesticide diffusion
Tying	• Tying tool and holding tool (two arms-one robot or two arms-two robots)	Electric tying tool: quick, light, adjustable tying options depending on thickness of canes. Holding tool: same as in harvest.	• Canes detection • Wires detection • Bend canes without breaking/ injuring • Tying the cane and the wire together

2.2. Spraying

For the treatment of diseases and insects of the vine, preventive spraying is performed. Ideally, spraying should be performed in the underside of each leaf first, and then from the top of the vine down to the bottom [19]. Traditionally, vineyards are sprayed with large spray tanks towed by tractors, manual sprayers, or by air.



(a) (b) (c)

Figure 2: Automation of spraying with (a) a moving spraying tube, (b) a moving multiple spray nozzle and (c) a customized spraying machine.

2.3. Tying

After pruning, the two new canes are laid and tied down on the trellis wire, one in each direction [20]. Optimal execution of tying requires skillful handling so as not to injure the canes. Therefore, automation of this practice requires a holding tool to bend and hold the cane close the wire and an electric tying tool to tie them together.

3. Conclusions

This work investigates the design of a multi-purpose robotic system towards automation of a set of basic viticultural practices. The aim of this work is to focus on the possibilities regarding these robotic automations, which in their entirety have never been employed to a single robotic system, by proposing end-effector tools for each one of them. Future work will include the overall system structure, in terms of software and hardware technologies.

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